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Land availability of Jatropha production in Malaysia

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ABSTRACT

This study reports the conversion of *Jatropha curcas* oil to biodiesel catalyzed by sulphated zirconia loaded on an alumina catalyst using response surface methodology (RSM). Specifically, it studies the effect of interaction between process variables on the yield of biodiesel. Jatropha is found to be survived in different locations in South-East Asia. Jatropha oil is favoured to palm oil for its cold filter plugging the point (CFPP) values, making it a better option for use in cold climates. The increasing industrialization and modernization of the world have to a steep rise for the demand of petroleum products. Economic development in developing countries has led to huge increase in the energy demand. The crude oil demand of the country is met by imparting about 80%. Thus, the energy security has become a key issue for the nation as a whole. Petroleum-based fuels are limited. This article is an attempt to present the prevailing fossil-fuel scenario with respect to petroleum diesel, fuel properties of biodiesel of biodiesel resources for biodiesel production, processes for its production, purification, etc. At last, a discussion of stability of biodiesel is described here.

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Contents

1. Introduction

Large scale of energy crop production requires large land areas that could lead to change in agricultural land-use patterns. Due to the demands of differing soil conditions, Jatropha is found to survive in different locations [1]. In South-East Asia, prefers that bio-fuel formers to differentiate the location by referring to it as the Jatropha belt or oil palm areas. Energy crop production competes for land uses that are meant for food production, forestry or environmental protection and nature conservation [2]. An overview of Jatropha planting is the possibilities and consequences of using agricultural land in a country or region for commercializing. Jatropha belongs to a large family; Euphorbiaceous and its genus include about 175 different plants [3]. Jatropha-Curcas is a perennial sub-tropical shrub that produces oil-rich seeds. Jatropha is unique in the sense that it thrives on semi-arid regions is highly adaptable and requires a

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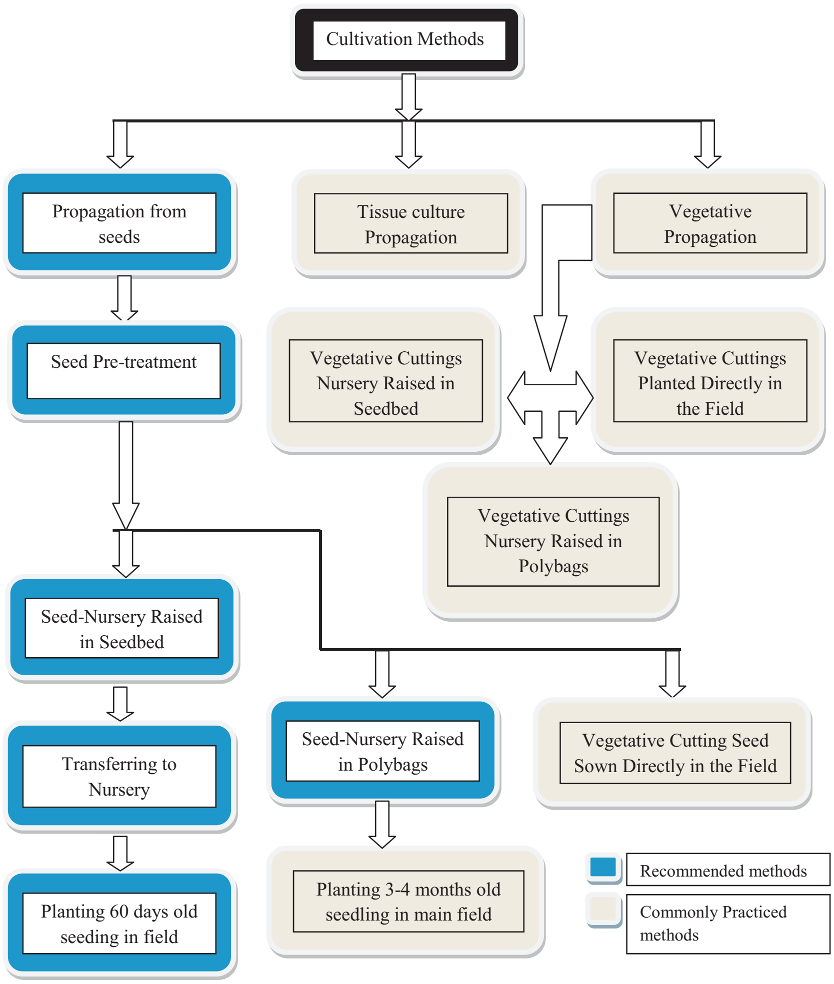

Fig. 1. Flow chart in Jatropha Cultivation methods [8].

limited nutrient. The oil from the Jatropha plant can be used to run diesel energy and fuel a lam [4,5]. The plant itself can improve soil quality to be used for other crops in the future. While usage is still at nascent stage, numerous reports had indicated that Jatropha can be a multipurpose plant, and its full potential is far from being realized [6]. Jatropha is a second generation biodiesel feedstock; it overcomes key challenges that the first generation biodiesel feedstock's faced food vs. fuel dilemma, problems in scalability and inability to grow in marginal lands. However, there are a number of exaggerations about Jatropha and the reasons why the plant has potential to be an excellent biodiesel [7].

The objective of this study is to find the possibility of land used for Jatropha plantation in Malaysia and its effect on other crops and on the economy of the country. Furthermore, study the importance of Jatropha cultivation based on green plantation, environmental issue in Malaysia.

2. Expose to view the plant of Jatropha

The views and advantages of the plant make it a useful plant with a number of potential applications in future [8,9].

- Unlike soybeans, canola and many other agricultural sources of biodiesel, Jatropha can be cultivated on marginal and non-agricultural land. This implies that growing Jatropha will not result in forgoing food crop cultivation.
- It starts producing seeds within 12 months but the effective yield is obtained only after 2–3 years.
- Plant remains useful for 35–50 years.
- Seeds can produce around 35% oil content. Based on per acre production, Jatropha's yield is second highest, next to that of palm oil.
- It is quite simple to produce biodiesel from the Jatropha.
- The waste (de-oiled Jatropha seed extract) can be used to produce organic fertilizer because it contains high content of protein, nitrogen compounds and some anti-pesticide compounds. After 4 or 5 years of treatment with this cake, the soil of this original non-agricultural land will become suitable for planting food crops or trees for reforestation.

3. Some view of Jatropha cultivation

Cultivation practices are the key determination for achieving favourable yields from Jatropha. There is a misconception that the Jatropha plant requires little water, and that it requires almost no inputs in terms of fertilizers and pesticides [10]. The fact is that the Jatropha plant does require all these inputs and maintenance in amounts significantly lower than for many other energy crops [11]. When optimal planting methods are followed, the yields have been better than the average [12]. The recommended methods of cultivation inputs and related topics as below Fig. 1:

Every single step from the selection of seeds to harvesting, the recommended methods of cultivation are described in brief.

Table 1
Yields based on soil quality and some real life yield [7].

Year	Range of reported yields per hectare (Tons)	Most likely average yield per hectare (Tons)
1	0.250–1.25	0.50
2	1–2.5	1.5
3	2.5–5.0	3.0
4	5–6.25	5.0
5	6.25–7.5	6.5

Table 2
Quotation of prices from various countries, likely prices of Jatropha seed in future and real-life prices of seed [7,13].

Year	Average seed price ($/kg)
2005	0.1
2006	0.12
January 2007	0.12
July 2007	0.14
January 2008	0.2
July 2008	0.22
October 2009	0.28
April 2010	0.26
January 2011	0.34

Planting the seedlings with proper space is another important factors in Jatropha cultivation in Table 1. Based on the various estimates made by experts and data, the following is the consolidated yield data for Jatropha seeds [8,13].

3.1. Jatropha seeds

Oil is derived from the seeds of the Jatropha plant. The Jatropha seed contains 30–40% oil. To produce oil, the seed moisture has to be maintained and storage of seeds is important for continuous press operation because the availability of the Jatropha seeds is seasonal in Table 2.

3.2. Jatropha tree

Jatropha is a deciduous large shrub or small tree of 3–5 m in height. But under favourable conditions, it can attain a height of 8–10 m. The tree has a smooth grey bark when cut. The stems exude whitish coloured watery latex but become brittle and brown when dry [9]. Its leaves are green with pale-green with a length of about 6 cm and width of about 15 cm, 3–7 lobes with a spiral phyllotaxis. Hypostomatic and stomata are of paracytic type. Insects, ants, thrips, flies and bees pollinate and to form the flowers terminally and individually [15–18].

The petiole length is between 6 and 23 mm. Inflorescence forms in the leaf axial and yields approximately 10 or more ovoid fruits. During hot seasons, the female flower grows slightly larger and when there is an imbalance of a pistil late or stamina. It produces a higher number of female flowers. Fruits are produced several times during the year and production range may be also attributable to low and high rainfall areas as well as soil fertility in Table 3.

A three, bivalve coccid is formed after the seed matures and the fleshy excerpt dries. Once ripen for picking, the capsule changes from green to yellow in 2–4 months. The inner seeds are black and weigh about 727 g per 1000 seeds but averagely there are 1375seeds/kg.

3.3. Soil, water and climate conditions

From a commercial perspective, Jatropha would need a higher level of water usage so it may push for development of large-scale irrigation to enable multiple harvests that may cause long-term impacts on ground water resources. As water resources may be a limiting factor for commercial Jatropha development, there is a need to evaluate large-scale projects in ecologically fragile zones [19]. Claims about Jatropha's ability to bind soil need further research in different growing regions because large-scale land clearance may have a negative impact on soil quality [22–25]. Soil erosion is a major environmental threat to the sustainability and productive capacity of agriculture over the 40 years [20]. Nearly one-third of the world arable land has been lost by erosion and continues to be lost at a rate of more than 10 million ha/annum and with the increase in world population's food demand, will see a decline in per-capita food productivity [21]. However, experiences across the developing world have been quite varied reflecting complexities in local practices, soil, water and climatic factors [26,27]. With the growing interest in Jatropha, these projects are no longer conceptualised entirely for soil erosion control but rather for the purpose of economic and social benefits [28–30]. Most projects are now characterised by new agronomical and technological challenges posed by new production and conversion processes with the adoption of new rural business models and emergence of environmental issues impacting the long-term sustainability [31–35]. After all, Jatropha is a hardy plant with low water efficiency use of 3.68 and 2.52 mmol of CO_2 and H_2O respectively as compared to oil palm of 3.95–4.42 mmol of CO_2 and H_2O. It grows on well-drained alkaline soils with good aeration but root formation is reduced in heavy soils. Limited fertilizers containing small amounts of calcium, magnesium, sulphur and phosphate, can aid the growth significantly [7].

Table 3
Estimated Jatropha yield curves 2008–2020 oil yield (kg oil/ha) [6,17–19].

Year	New plantations		Existing plantations	
	High yield potential	Standard yield potential	High yield potential	Standard yield potential
2008	500	200	2400	1500
2009	1500	700	2410	1505
2010	2000	1300	2420	1510
2011	2300	1500	2430	1515
2012	2400	1520	2440	1520
2013	2500	1540	2450	1530
2014	2520	1550	2460	1525
2015	25,540	1560	2470	1535
2016	2560	1570	2480	1540
2017	2580	1580	2490	1545
2018	2600	1590	2500	1550
2019	2620	1600	2510	1555
2020	2640	1610	2520	1560

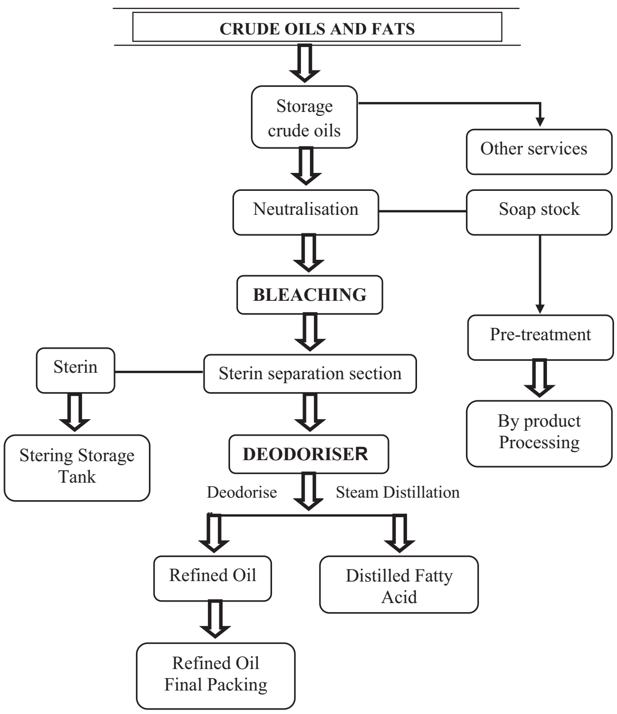

Fig. 2. Process flow for a typical Oil Refining Plant [7,36].

4. Jatropha oil production

Method of producing Jatropha oil is simple and machinery involved in the oil production is readily available [36,37]. This part provides detailed descriptions of the step-by-step processes in Jatropha oil production, and machineries involved in each process in Fig. 2. The overall Jatropha oil manufacturing process is:

Sowing ⇒ Cultivation ⇒ Harvest ⇒ Seed Dehulling and Cleaning

⇒ Oil Extraction ⇒ Oil Filtration and Purification ⇒ Oil Refining

5. Conversion of Jatropha oil into biodiesel

Biodiesel is the product of changing the triglyceride chemical structure of vegetable oil or animal fat to be a methyl ester. The chemical process in Fig. 3 is called the "Transesterification Process" [39]. The process mechanism is the reaction between crude Jatropha oil and methanol with sodium hydroxide or potassium hydroxide as a catalyst. The end product of the transesterification process is methyl ester or biodiesel. Furthermore, glycerine is produced as a by-product of this process [40–42].

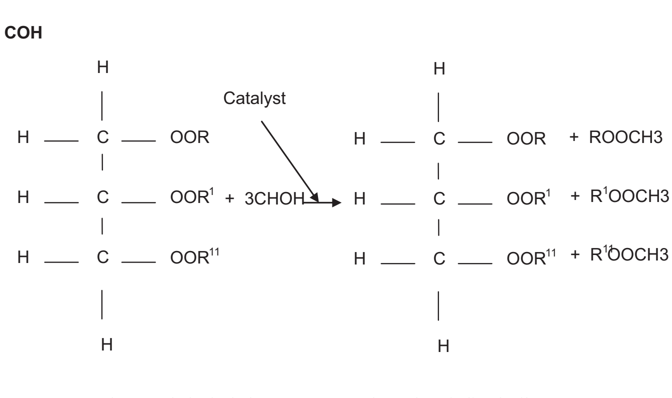

Fig. 3. Chemical reaction of Biodiesel production process [8].

6. Biodiesel characterization by *Jatropha curcas* oil

The fuel properties of Jatropha biodiesel were characterized, and it indeed met the specification for biodiesel according to ASTM D6751. The properties of extracted *J. curcas* oil, Jatropha biodiesel, conventional diesel and biodiesel standard are summarized in Table 4. It can be seen from this table that the property of *J. curcas* oil was found to have values beyond the boundaries of normal range of biodiesel properties, especially acid value and kinematic viscosity, thus restricting its direct use as a fuel for diesel engines [43,44]. The kinematic viscosity of the oil was found more than that of conventional diesel determined at 40 °C [45,46].

However, after transformation reaction, the acid value and kinematic viscosity of the oil decreased significantly. On the other hand, more than 100 °C, Jatropha biodiesel was found of conventional diesel leading to safer storage and handling [47,48]. Acid value for biodiesel is primarily an indicator for free fatty acid. Acid value higher than 0.8 mg KOH/g might cause deposition of FFA on fuel system leading to shorter fuel pumps and filters life span [49,50]. Furthermore, higher viscosity fuels can cause poor fuel combustion that leads to deposit formation. However, the properties of Jatropha biodiesel such as acid value, kinematic viscosity, flash point, specific gravity, water content and ash content have comparable fuel properties with those of conventional diesel and met the biodiesel standard of ASTM D6751 as shown in Table 4 [41–54].

7. Performance of mineral diesel and Jatropha oil in India

Agarwal and Agarwal [55] they worked in an engine used by Jatropha oil. In their paper, they developed schematic diagram of the engine. The engine operated at a constant speed of 1500 rpm. Fresh lubricating oil was the filled-in oil sump before starting the experiments. The engine is coupled with a single phase, 220 V AC alternator. The alternator is used for loading the engine through a resistive load bank. The load bank consists of eight heating coils (1000 W each). A variac is connected to one of the heating coils so that load can be controlled precisely by controlling voltage in one of the coils of a load bank. The schematic layout of the experimental setup for the present investigation is shown in Fig. 4.

The main components of the experimental setup are two fuel tanks (diesel and Jatropha oil), fuel conditioning system, and heat exchanger, exhaust gas line, bypass line and performance and emissions measurement equipment. Two fuel filters are provided next to fuel tank so that when one filter gets clogged, supply of fuel can be cleaned without stopping the engine operation [56,57]. The engine is started with diesel, and once the engine warms is switched over to Jatropha oil. In order to control the temperature of the Jatropha oil within a range of 80–90 °C, a by-pass valve is provided in the exhaust gas line before the heat exchanger. After a result, the diesel and Jatropha oils are analyzed for several physical, chemical and thermal properties shown in Table 5.

About the density, cloud point and pour point of Jatropha oil was found higher than diesel. Cloud point and pour points reflect unsuitability of Jatropha oil as diesel fuel in clod climatic condition. The flash and fire points of Jatropha oil were quite high compared to diesel. Hence, Jatropha oil is extremely safe to handle. Higher carbon residue from Jatropha oil may lead to higher carbon deposits in a combustion chamber of the engine. CHNOS (carbon–hydrogen–nitrogen–oxygen–sulphur) were measured for diesel and Jatropha oil. Low sulphur content of Jatropha oil results in lower SO_x emissions. Presence of oxygen in fuel improves combustion properties and emissions but reduces the calorific value of

Table 4
Jatropha biodiesel fuel properties with ASTM D6751 standard [7,38–41].

Property and unit	Extracted Jatropha oil	Jatropha biodiesel	Diesel	Biodiesel standards ASTM D 6751
Acid value (mg KOH g^{-1})	10.37	0.29	–	<0.80
Kinematic viscosity at 40 °C ($mm^2 s^{-1}$)	48.2	2.9	2.6	1.9–6.0
Flash point (°C)	60	140	68	>130
Specific gravity (g ml^{-1})	0.92	0.89	0.85	0.86–0.90
Water content (%)	0.05	0.01	0.02	<0.03
Ash content (%)	0.09	0.01	0.01	<0.02

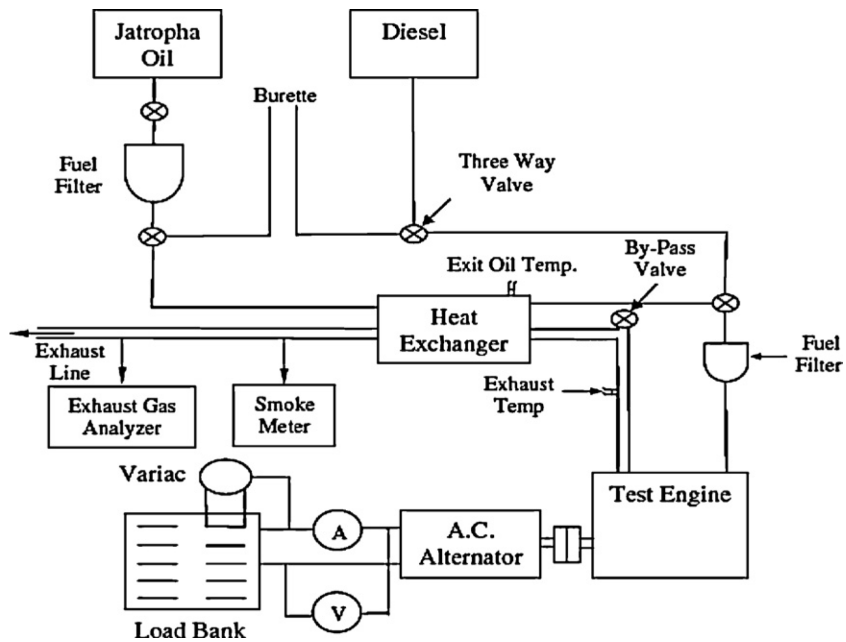

Fig. 4. Schematic diagram and experiment setup [55].

the fuel. Jatropha oil has approximately 90% calorific value compared to diesel. Nitrogen content of the fuel also affects the NO_x emissions (by formation of fuel NO_x)

8. Jatropha in South East Asia

Regionally, Thailand and Indonesia are more into Jatropha cultivation while some reports had identified small-scale cultivation in Myanmar and Laos [58,59]. The Malaysian government has no immediate plan to divert national resources to Jatropha as this might disrupt the palm oil plantation equilibrium. At present, Malaysia is concentrating on increasing the yield per hectare of Crude Palm Oil due to the disadvantage of not having vast plantation land like Indonesia [60–64]. Malaysia's plantation culture is keener on R&D, consequently, is the last country in the South East Asian region to jump onto the Jatropha bandwagon [65–67]. Most of the Malaysian companies involved in Jatropha production do not plant themselves but are involved into R&D of Jatropha and commercialisation of biodiesel. Table 6 shows a view of an agricultural production of the five major stocks and bio-fuel energy [68,69].

There is a plan to grow Jatropha elsewhere like in China, India or Indonesia as these countries provide a ready-made potential market. Consequently, China, India, Indonesia, Cambodia and Thailand are all ahead of Malaysia right from the upstream to the downstream, even coming up with the various by-products that include soap, pig feed and medicinal drugs to treat some cancer [70–73]. There is no estimate of how much Jatropha is being planted or cultivated in Sarawak but anecdotal evidence suggests the trend is accelerating [74,75].

Table 5
Properties of mineral diesel and Jatropha oil [51].

Property	Fuel	
	Mineral diesel	Jatropha oil
Density (kg/m^3)	840 ± 1.732	917 ± 1
API gravity	36.95 ± 0.346	22.81 ± 0.165
Kinematic viscosity at 40 °C (cSt)	2.44 ± 0.27	35.98 ± 1.3
Cloud point (°C)	3 ± 1	9 ± 1
Pour point (°C)	−6 ± 1	4 ± 1
Flash point (°C)	71 ± 3	229 ± 4
Fire point (°C)	103 ± 3	274 ± 3
Conrad son carbon residue (%, w/w)	0.1 ± 0.0	0.8 ± 0.1
Ash content (%, w/w)	0.01 ± 0.0	0.03 ± 0.0
Calorific value (MJ/kg)	45.343	39.071
Carbon (%, w/w)	80.33	76.11
Hydrogen (%, w/w)	12.36	10.52
Nitrogen (%, w/w)	1.76	0
Oxygen (%, w/w)	1.19	11.06
Sulphur (%, w/w)	0.25	0

9. Jatropha in Malaysia

Malaysia has about of 1.5 million ha of marginal land and the take-up rate for growing Jatropha is rising albeit on a gradual curve [76,77]. Going by the oil palm experience, Malaysia's expertise is more inclined towards plantation management. Malaysia cannot afford to destroy the rainforest as there is still a lot of poor land between 30°N and 30°S [78,7]. ARK Bio Sdn Bhd is the biotechnological arm of Cosmo Bio fuels Sdn Bhd that focuses on

Table 6
Production of major Biofeedstocks [6,59–61].

Agricultural production of the five major feed stocks and bio-fuel energy yields in 2005										
	Bio-fuel type									
	Bio-ethanol						Biodiesel			
	Bio-fuel crop									
	Maize		Sugarcane		Cassava		Soybean		Oil palm	
Country; top 2 crop producers	USA	China	Brazil	India	Nigeria	Brazil	USA	Brazil	Malaysia	Indonesia
Total production million tons	280	133	420	323	42	26	83	50	76	64
% world production	40	19	33	18	20	12	39	24	44	37
Average crop yield, '03–'05 tons/ha	9.4	50	73.9	60.7	10.8	13.6	2.7	2.4	20.6	17.58
Conversion yield Litres/tons (a)	399	399	74.5	74.5	137	137	205	205	230	230
Bio-fuel yield in gigajoules/ha (b)	3751	1995	4522	4522	1480	1863	552	491	4736	4092
Energy yield in gigajoules/ha (c)	79.1	41.1	95.4	95.4	31.2	39.3	18.2	16.1	156	135
2005 petroleum (d) replacement, % of petroleum use	2.0	2.4	1.8	1.8	-	-	0.1	-	-	-

the development of improved genetic material and mass propagation of planting material for Jatropha, other oil seed plants and organisms, which can be utilised as feedstock for the bio fuel industry [79–82]. It also has collaboration with research institutes on agronomy, plant nutrition and farm mechanization, among others. Cosmo meanwhile is engaged in establishing Jatropha plantations, biodiesel downstream processing and trading activities in the Asia-Pacific region. The components of bio fuel in Malaysia are available in Table 7.

Together with its strategic partners, Cosmo has upstream projects in Thailand, Cambodia, Vietnam, Indonesia, the Philippines and China. Jatroleum was established in 2006 with a pilot plantation in Kuala Pilah [83]. It is also involved in a 10,000-ha plantation in Cambodia with a nongovernmental organisation to train farmers in Jatropha cultivation. In 2008, the company embarked on a pilot project of 1000 ha in China's eastern Fujian province, which is ready to be cultivated on a commercial basis [84]. According to a news report, the company hopes to tap China's burgeoning biodiesel market. NSP specializes in providing plantation advisory services [85–89]. The company credits its strong business growth to its distinctive management practices that stress on continuous improvement in yields [90]. It has a team of in-house planters that conduct analysis and studies with the objective of ensuring that best practices for sustainable agriculture are adhered to [91]. BioNas is wholly owned by BATC Development. Bhd is a stockist engaged in the trading of Jatropha seedlings and oil for bulk shipment [92]. They assist local farmers to venture in Jatropha planting and had a guaranteed buy back price scheme of RM850/ton. Using phenotype of Jatropha developed by the Luhat Technology Institute and Passion Masters will embark on a Jatropha plantation and processing facility in the Sarawak Corridor of Renewable Energy [93–96]. They had identified locations in Belawai, Jerijeh, Tanjung Manis and the Rajang area in Mukah division for cultivation of the Jatropha Superbulk variety covering 809 ha [97–100]. Jatropha Superbulk would be the main feedstock for a bio fuel processing facility in Tanjung Manis. As of the first quarter of 2009, the nursery in Jerijeh will provide two million seedlings for planting [101–103].

Table 7
Malaysian wild Jatropha oil components [6,64,65,71–74].

Component	Weight %
Moisture	60.2
Protein	18
Fat	38
Carbohydrate	17
Fibre	15.5
Ash	5.3
Tri-glycerides of oleic acid	34–45
Linoleic acid	31–43
Palmitic acid	14–15

9.1. South-East Asia–Malaysia (Jatropha existing land and commercial farmed)

At present, no policy or legislation specifically supporting Jatropha cultivation exists, but is reported to be currently drafted. It is so far the development of Jatropha cultivation has been comparatively slow in Malaysia, and any project activities are still on a low way. Most projects have only been set up recently and mainly run by foreign-owned companies with little exception [104–106]. It is shown in Fig. 5 that the land for Jatropha cultivation is identified in Malaysia [107–110].

The main reasons for the reluctant development are apparently high costs for land acquisition (compared with neighbouring states) and a shortage of low cost labour. The report from the country experts is that, small-scale farmers have not yet started to grow Jatropha [112]. However, the total current land has been identified 1712 ha. Project owner's state plans to increase the cultivation scale to a total of 57,601 ha by 2015 [89,98]. The Ministry of plantation of industries and commodities is undertaking a Jatropha pilot research project for which 300 ha have been allocated. Some international, leading oil company report plans to develop Jatropha projects in Malaysia [113,114]. A few local private companies have engaged in Jatropha cultivation from 400 ha to 1000 ha.

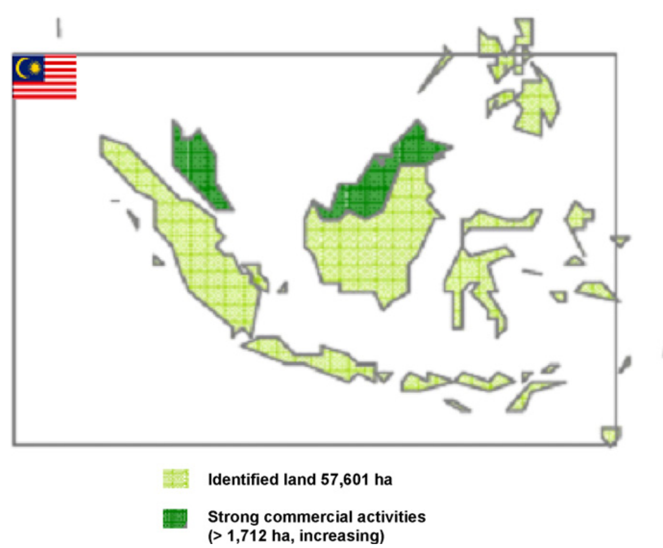

Fig. 5. Jatropha exist land and commercial area in Malaysia [111].

9.2. Report on J. curcas in Malaysia

The first national workshop on renewable energy from *J. curcas* was held in 2008. Ms Mayli Lim said: "The current status and future direction of *Jatropha curcas* as a source of biodiesel". Agronomic and management practices of Jatropha cultivation in Malaysia, report by En Mansur Puteh (Research officer in the rice and industrial crops centre), Malaysian Agricultural Research and Development Institute (MARDI) touched on the current research initiatives undertaken at MARDI for Jatropha along the production value chain and shared experiences on the various agronomic and management aspects on the crop. Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia discussed the opportunities and constraints in commercial production of Jatropha, including some economic and entrepreneurial considerations [23,42,115].

The First National Workshop of Renewable Energy from *J. curcas* – The Way Forward had instilled a lot of awareness and interest among potential Jatropha cultivators in the light of the price hike of fossil fuels. The workshop recognized the pertinence issues of the needs of establishing mechanism of overcoming the challenges of exploring the benefits to the rural community and the roles of various public–private partnerships to work on the economics and financial model for the Jatropha industry [14,115].

10. Conclusion

The supporters of Jatropha have argued that it will be succeeded without irrigation and therefore, does not compete for water or displace food production from prime agricultural land. Jatropha has entailed multi-dimensional livelihood impacts for farmers that were unevenly distributed across classes. They would be still in place even if some new high-yielding varieties spread with increased output or subsidized input prices, which would make Jatropha economically viable and attractive to farmers. Jatropha is not a magical crop that will give the farmer much more wealth than other crops. It needs to be treated as any other productive crop. Proper research, planning and implementation need to be done for cultivation in order for the crop to provide sustainable profits. India is a densely populated country and they fallow land holding per farmer is 1–10 acres. A farming family can take care of this size of land very easily, as far as plantation, harvesting as well as security is concerned. The infrastructure of roads, housing and market are already available in the villages. This infrastructure substantially reduces cost, as compared to plantations on barren, vast and inhabited lands. This paper highlights that most of the Jatropha projects in South East Asia have to issue with limitations of arable land that are diverted for bio fuel use taking up resources and land that otherwise could have other sustainable uses. However, Pyakuryal suggested that the adoption of Green Technology such as bio fuel, biogas, biomass, bio transgenic, organic farming, integrated pest management (IPM), agro forestry can increase agricultural output without depleting presently available resources beyond the point of recovery. Many countries actively promote investments in renewable energies (e.g. Ghana, Tanzania, Malawi or Kenya) or facilitate the access of land to interested investors. On the other hand, energy markets could determine agricultural commodities value and help to reverse the long-term trend of declining real prices for the global bio fuels market.

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